Section 7 – Bridge Design Aesthetics

Contents

Bridge Design Aesthetics

7.1.0 Preface

7.1.1 Definition

Aesthetics — The science or study of the qualities of beauty, including surrounding light, shadow, and color not limited to physical forms.

Beautiful Bridge — A beautiful bridge makes a minimal impression on the environment, has good proportions both in its integral parts and in the space outlined by its parts. It is composed of one dominant structural system using a minimum number of bents with a minimum number of columns per bent. Size, shape, color, and texture on superstructure, columns, and abutments are utilized to either call attention to, or play down, the role of these structural parts.

7.1.2 Scope

The inexact science of aesthetics is limited to practical application in bridge design where cost, construction, and maintenance compete with public acceptance. Consult the bibliography for philosophy, history, and ethics.

7.2.0 Introduction

7.2.1 General

7.2.2 Project Development Team

CALTRANS has incorporated the design team concept into its normal project development process. This team is composed of professionals from all disciplines participating in the design process. Representatives from engineering, architecture, environmental studies, landscape architecture, and legal are directly and indirectly incorporated in the project development team. The Division of Structures type selection meeting members represent the structural engineering function of the project development team.

7.2.3 Design Philosophy

Design philosophy from top management to the design team encourages beautiful structural design while following the rule that "form follows function." The end result can be an aesthetically pleasing structure that is also economical.

7.2.4 Method

The method utilized in most CALTRANS structure designs consists of modifying the standard shapes required to perform the structural function. These modifications are achieved by using grooves, offsets, texture, and cross sectional changes.

7.2.5 Results

This approach results in using a standard enclosure which is basically rectangular in shape, both in cross section and longitudinal section for girders; and round to rectangular for columns. Only when we extend this technology to its upper limit do we consider the need to reduce mass. We generally accept redundant mass in order to simplify form work which is the basis for our cost effective design. Concrete is the primary construction material. Special site or public relations problems require the designer to marry architecture and engineering by using engineering dictates such as moment diagrams to provide the basis for a design subject to strict cost/function criteria.

7.3.0 Bridge Design and Aesthetics

Section 7.1.1 defines a beautiful bridge for the purpose of directing bridge designers. CALTRANS bridge engineers attempt to make every bridge a beautiful bridge. They produce advance planning studies, or the equivalent, to discuss aesthetics with the Aesthetics and Models section (A&M). A&M coordinates with bridge engineers using visual aids to identify areas of aesthetic concern and to resolve these areas of concern. Interaction of A&M and engineering personnel is necessary as early as possible to coordinate Division of Structures' work with the Project Development team.

7.3.1 Theory

Bridges affect their surroundings by their size, shape, and color. CALTRANS has determined bridges should be a good neighbor. They should be compatible with their environment and blend rather than make a strong statement.

There are two basic positions for viewing a bridge: (1) the position of the bridge user and (2) the position of a viewer looking at the bridge from a location to the side of the bridge.

The bridge user should be presented with a minimum of distractions. Therefore, the best bridge is one where the user is not able to determine that he is using a bridge. The second position is generally dependent upon the elevation or profile presented by the bridge.

The profile view describes the structural type such as arch, truss, girder, suspension, or stayed girder. Sound structural design (1) function, (2) and appropriate aesthetic treatment, (3) have been established as the order of priority. The first priority must begin with geology to determine where supports may reasonably be located. The structural type is therefore dependent on possible support in order to determine the span lengths. Technology has made it possible to have single-span lengths of over 200 feet in concrete. This base can be expanded by using steel and adapting a continuous span procedure to extend the limit. Increasing the apparent height of the structural type by constructing a truss, combining a truss with an arch, building towers, and suspending the deck by stays or suspension cables are other methods of increasing span lengths.

The problem of economically producing large numbers of bridges necessitates the implementation of a repetitive process. Basic methods and procedures must remain as simple as possible; therefore, the least complicated method and procedure must be the starting point for selecting structural type. Actual physical and monetary conditions modify this beginning toward an increasingly complicated problem.

A parallel exists in aesthetics. The second and third priority may modify the choice of structural system. Bridges constructed to serve transportation junctions are large structures. Therefore, the appropriateness of the structural system is the most important factor in bridge aesthetics. This factor can be seen from any position from which the bridge can be viewed. It is the bridge. The architect can bring out the aesthetic qualities of the structural system but can never change its basic impression.

7.3.2 The Structural Type

Aesthetic Considerations

Each route should be composed of bridges with an appearance compatible with other bridges on the route. Overcrossings should contain the aesthetic theme for the route. Undercrossings may vary from the route theme to satisfy local community requirements.

River crossings and viaducts are usually not within the driver's focused viewing area; therefore, they may also vary from the route theme. However, close resemblance to route theme bridges will produce a desirable unified appearance for the entire route.

7.4.0 Type Selection Meeting

The type selection meeting is attended by representatives from Specifications, Maintenance, Construction, Estimating, Design, and Aesthetics and Models. The purpose is to provide a bridge with qualities which will satisfy all members of the Division of Structures. The results of this meeting will be "sold" to CALTRANS. The District and the consultant are also present for Externally Financed Projects.

7.4.1 Preparation for Type Selection Meeting

The engineer is in charge of producing contract plans. Aesthetics and Models acts as the engineer's consultant. Advance Planning Studies prepared by the engineers are reviewed by Aesthetics and Models. These reviews consist of selecting column type, girder edge treatment, and surface treatment. A preliminary architectural sketch is drawn consisting of section, elevation, and a rough perspective. Cost estimates are prepared, and the suitability of structural design to architectural features and cost are determined before work progresses.

Planning and recommendations by Aesthetics and Models begins with research of the area and route to be occupied by the bridge. These recommendations also incorporate directions or information gathered at public meetings.

7.4.2 Public Meetings

Public meetings may be workshops organized by the District to produce facilities incorporating a style, theme, or artistic feature required by the community. Workshops are occasionally scheduled to insure that features required by the community are presented at public hearings. Public hearings are usually designed to present the community with a proposal or alternate proposals in order to secure a freeway agreement.

Public meetings may be scheduled either before or after type selection meetings.

7.4.3 Visual Aids

Presentation quality material to be displayed at public meetings or District meetings is available from Aesthetics and Models. Artwork ranging from simple sketches to photo retouches showing the proposed product in its environment is also available from Aesthetics and Models. These displays require from one week to two months to produce.

Models may also be ordered. The equivalent of a sketch is a styrofoam model. Elaborate models which correspond to photographic retouches require six months to a year to construct.

Design sections may order visual aids by sending a memo to Aesthetics and Models.

The memo should include the type, size, and completion date required. Districts usually order the large elaborate models showing interchanges with several bridges within a community. This type of visual aid, requiring relatively long construction periods, must be ordered by a letter to the Chief of the Division of Structures.

7.5.0 Aesthetic Feature Guidelines

Figure 1 illustrates the bridge parts normally given aesthetic consideration. This work involves scrutinizing the required structural shape with regard to appearance criteria developed by the Aesthetics and Models Unit from public meetings, District requirements, and aesthetic judgement.

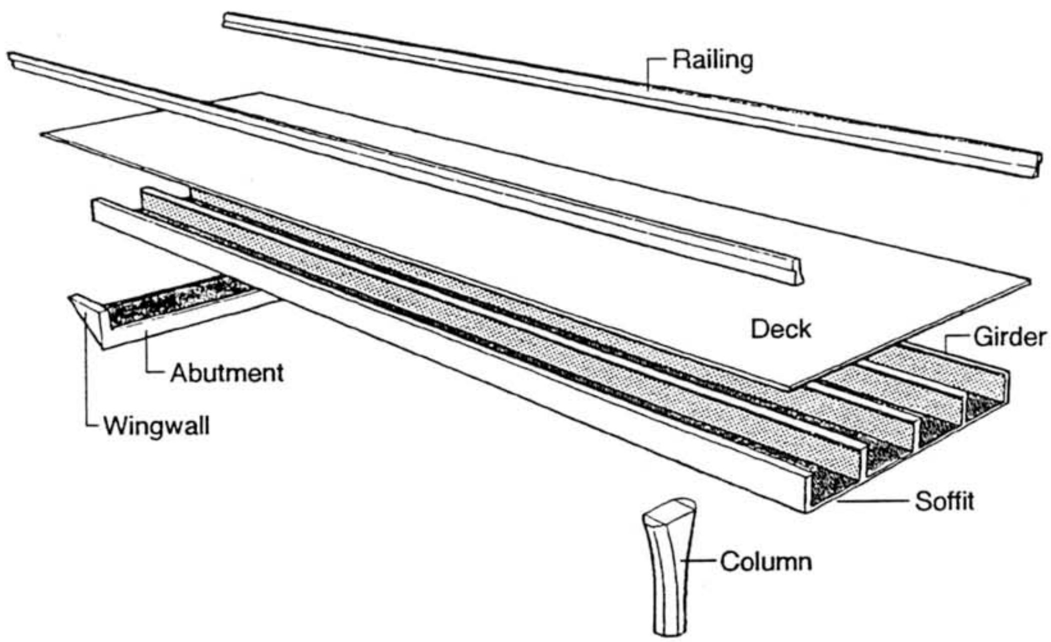
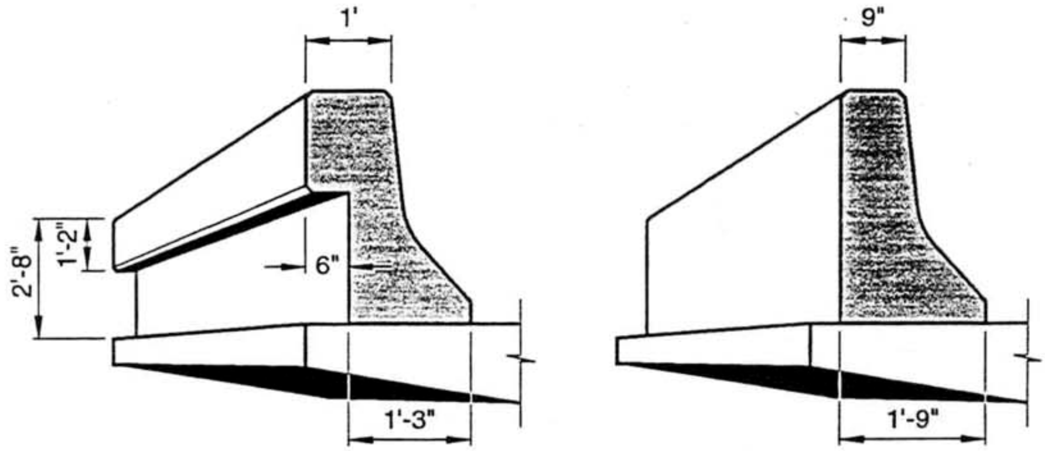


Figure 1. The Parts of a Bridge

7.5.1 *Railings*

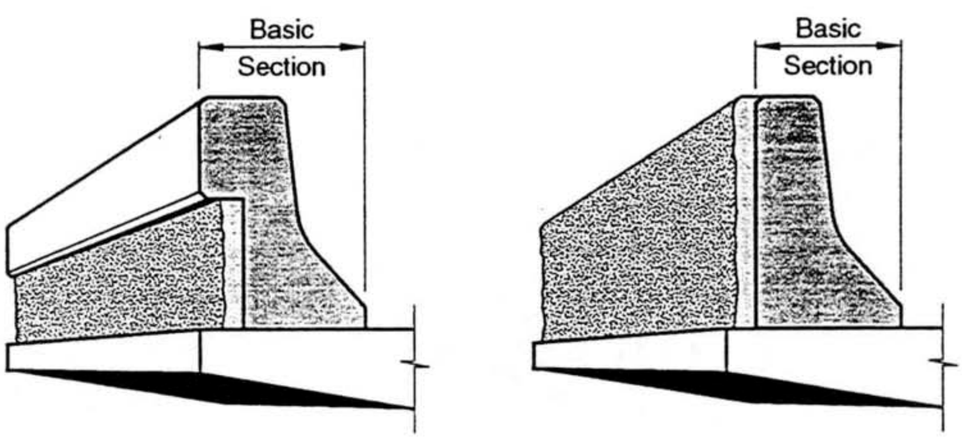
Type 25 and Type 27 form the basis for our work. The only modification allowed is to stain or paint the depressed or grooved area on the outside face of Type 25 (Figure 2).



Type 25 Type 27

Figure 2

Texture or shape change to the outside face requires the railing to be designated Type 25M or Type 27M (Figure 3). The texture must be added to the basic structural section.



Type 25M
Minimal Texture

Type 27M
Minimal Texture

Figure 3

7.5.2 Girders and Decks

a) Figure 4 illustrates the basic girder and deck assembly wherein the girder and deck are combined to form a slab. Aesthetic consideration for slab bridges are generally confined to limiting the apparent thickness (t) of the outside edge of the slab. "t" should be approximately equal to the corresponding dimension for box girder bridges (Figure 5).

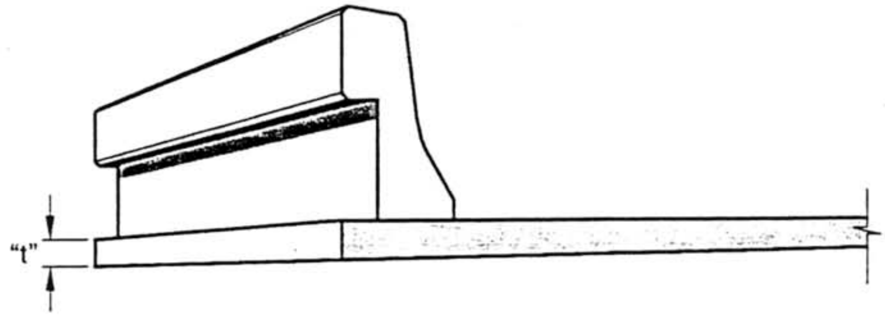


Figure 4. Slab Deck

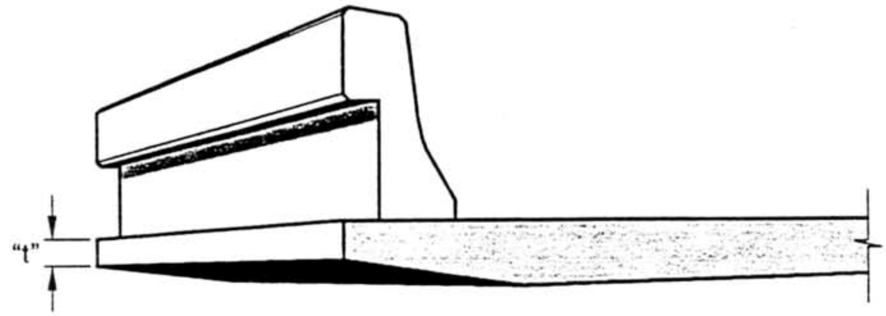


Figure 5. Slab Deck with Sloping Edge

b) Bridges constructed using steel and reinforced concrete rely on the tensile strength of steel. These bridges do not require the massive abutments used for compression force structures. Our tension force structures demonstrate the physical ability of tension structures to be much thinner or require less depth than compression structures.

Bridges that appear to be horizontal constructions appear, from an artistic point of view, stable and graceful. Thin horizontal bridges with a minimum number of columns are desirable.

Work in Aesthetics has focused upon applying the previous statement. Horizontal lines and shadows are the devices employed by the architect to produce bridge designs which have been labeled clean, functional, and honest.

c) The exterior girder of the box girder system can be arranged to enhance the perception of small depth or thinness.

Figure 6. Shadows cast by the overhang on the exterior girder place the exterior girder in shadow similar to the shade always present on the soffit.

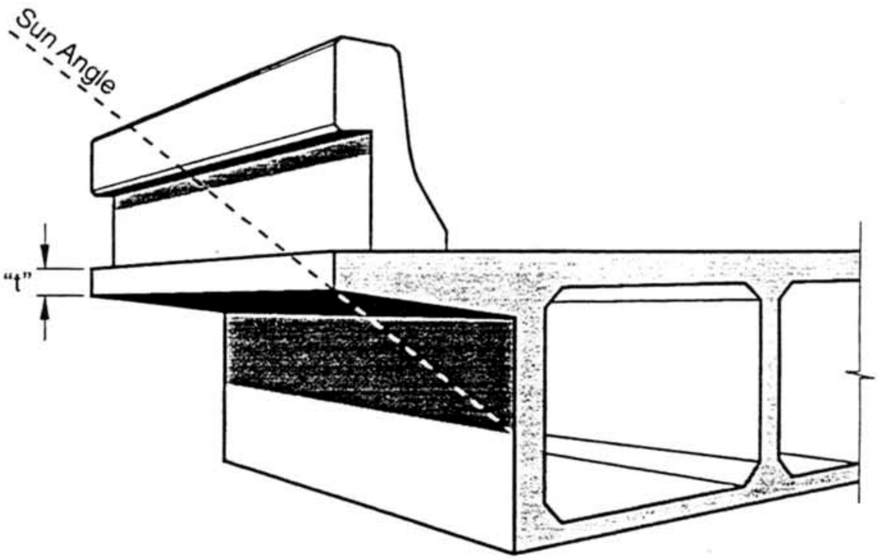


Figure 6. Concrete Box Girder with Vertical Sides

The amount or depth of the exterior girder shadow is dependent upon the overhang length, the sun angle, the exterior girder angle, and the relative north-south orientation of the girder.

Maximum enhancement, thinness, is achieved when the shade of the soffit merges with the shadow on the girder (Figures 7 and 8). The railing and edge of deck are the only elements remaining in sun (Figure 8).

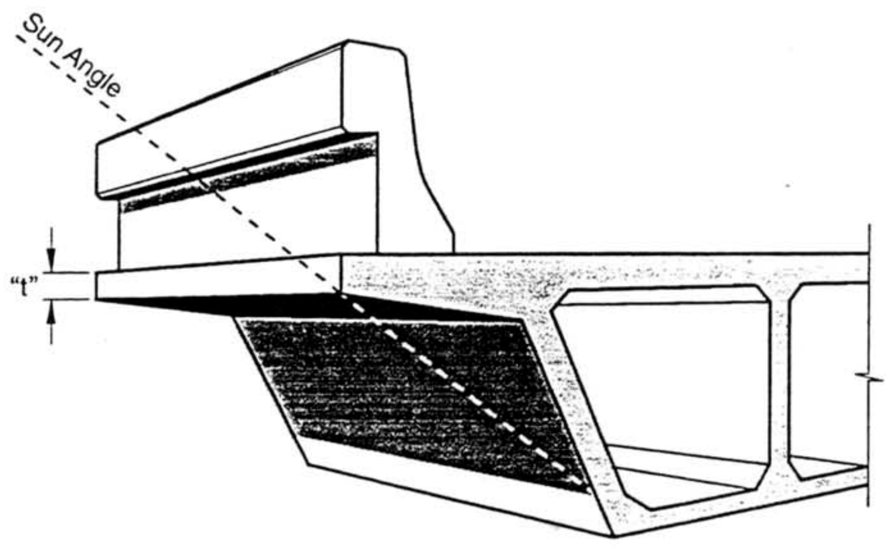


Figure 7. Concrete Box Girder with Sloping Sides

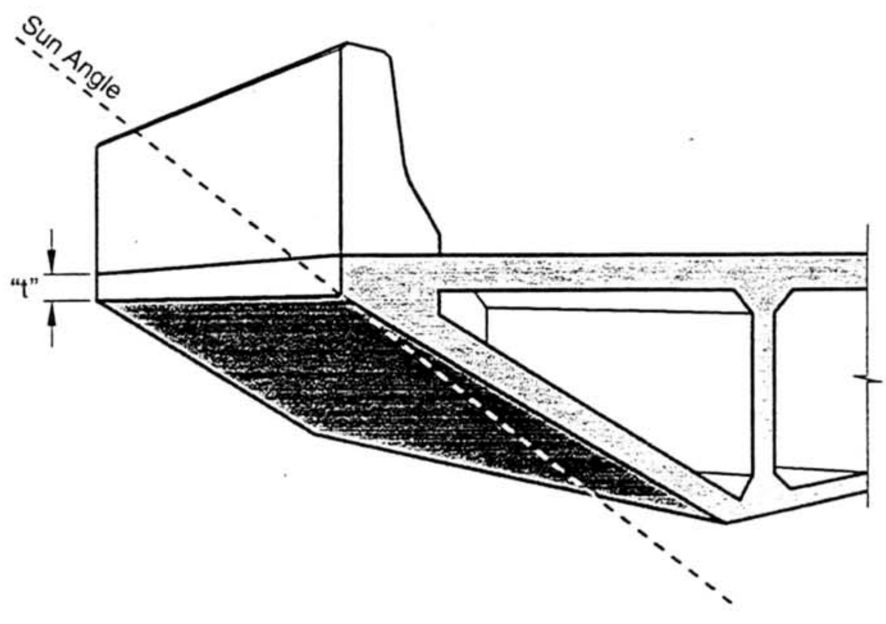


Figure 8. Concrete Box Girder with Sloping Sides (No Overhang)

7.5.3 Columns

Standard architectural columns have been designed as a series of modular shapes. Cross sections are available in round, octagonal, and hexagonal forms. These forms can be expanded to include a rectangle between the basic form. A round cross section can become a cross section that is semicircular at the edge with flat sides joining another semicircular edge. This system is used for all the geometrical forms to increase the load bearing ability of a single column. Therefore, a minimum number of columns can be used. The edge column directly adjacent to the viewer provides the impression of column width that the viewer normally perceives. This impression is controlled by light reflecting from the column edge. Octagonal columns appear slimmest as a result of the greatest number of surfaces. The viewer sees a large area broken up by several planes. Round columns are affected less and square or rectangular columns are not affected. The architect can take advantage of this light reflection by using the principles to slim down a massive column or increase the apparent size of a column to offset a massive superstructure. Column proportions, therefore, have a large effect on the aesthetics of bridges.

Columns that appear larger than necessary to support the superstructure are not desirable because attention is directed away from the primary purpose of a bridge, which is to provide free movement. Columns that are obviously needed to support the superstructure should appear to be of sufficient size to perform their function. Columns that appear thinner than the visual requirement impart the feeling of possible collapse to the viewer.

The upper part of standard architectural columns is curved, arched, or flared to visually integrate the column with the superstructure. This spreading outward of the standard architectural column is designed to be compatible with the sloped exterior girder of a trapezoidal box girder (Figure 9). Standard, flared architectural columns are not compatible with vertical exterior girder shapes (Figure 10). A transition between the column and the superstructure similar to the capital on classic style columns must be introduced (Figure 11). This "capital" usually takes a simplified form involving straight lines tapering in the opposite direction of the flare for a distance less than the girder depth. The capital actually becomes an exposed column cap, or part of an exposed column cap. This treatment is effective only when the extremities of the flare are wider than the superstructure.

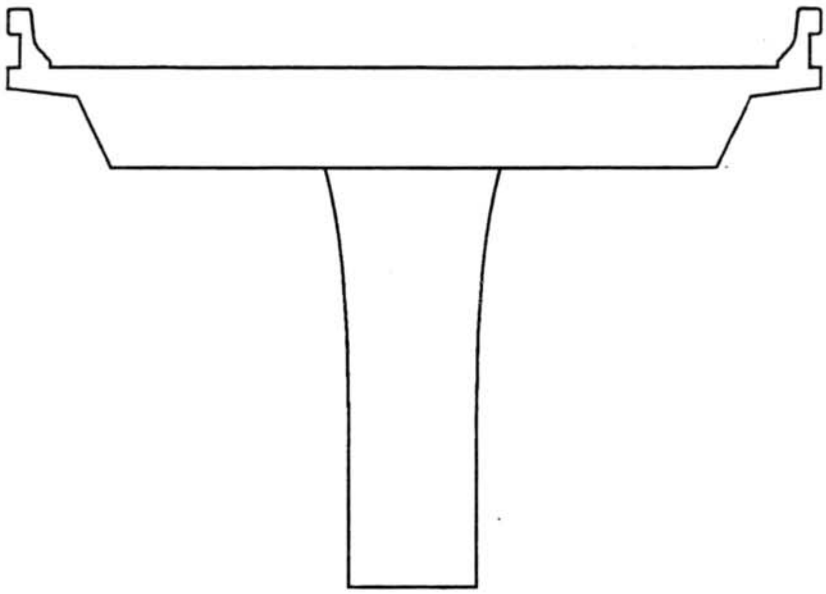


Figure 9. Compatible — Recommended

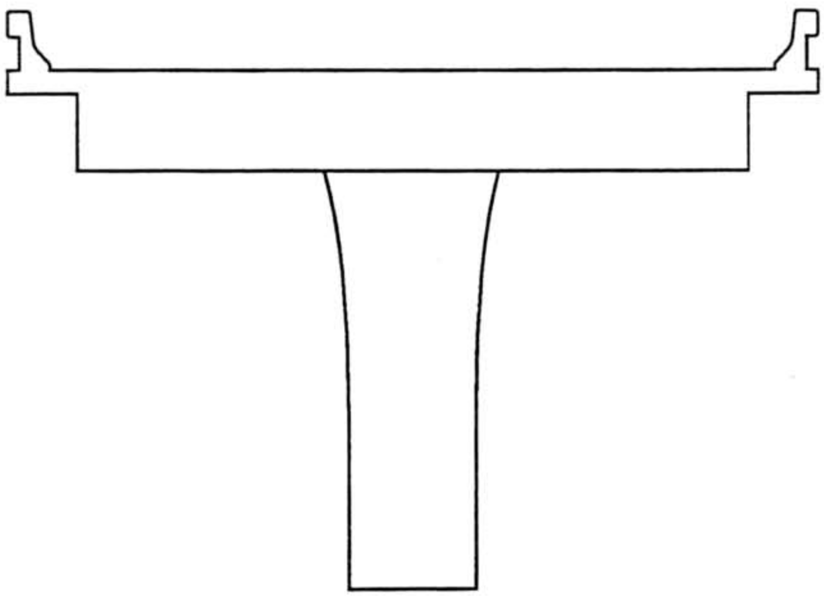


Figure 10. Incompatible — Not Recommended

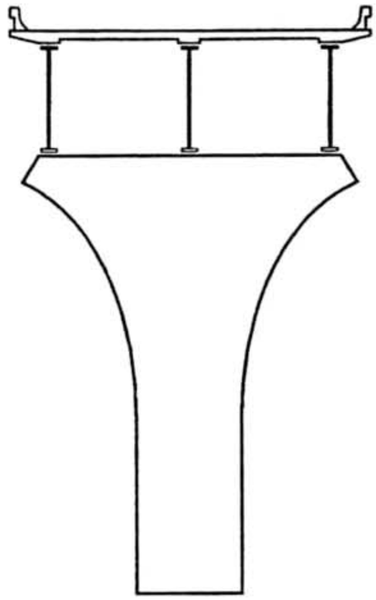


Figure 11. Acceptable

Vertical exterior girders should be used with prismatic columns (Figure 12).

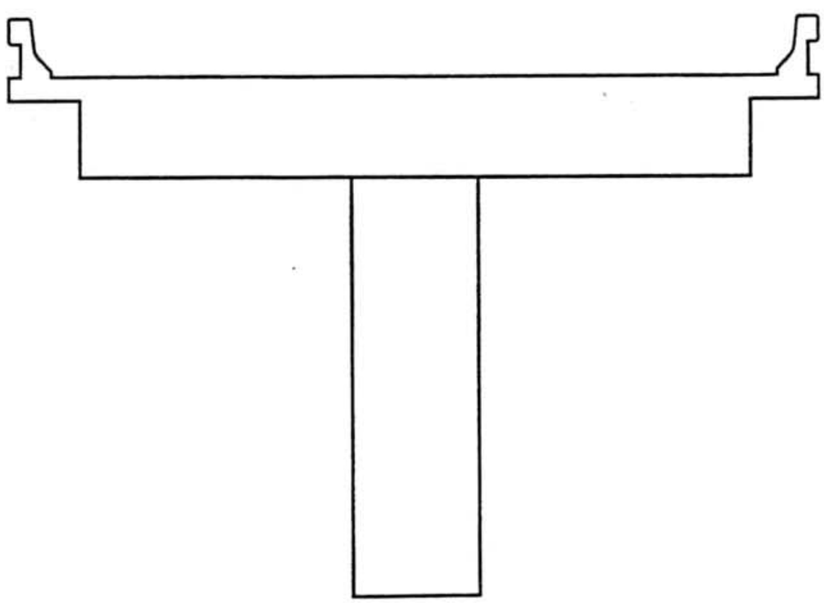


Figure 12. Compatible — Recommended

Flared columns as described previously are designated as one-way-flare columns (Figure 13). They promote flow perpendicular to the bridge and under the bridge; therefore they are directional.

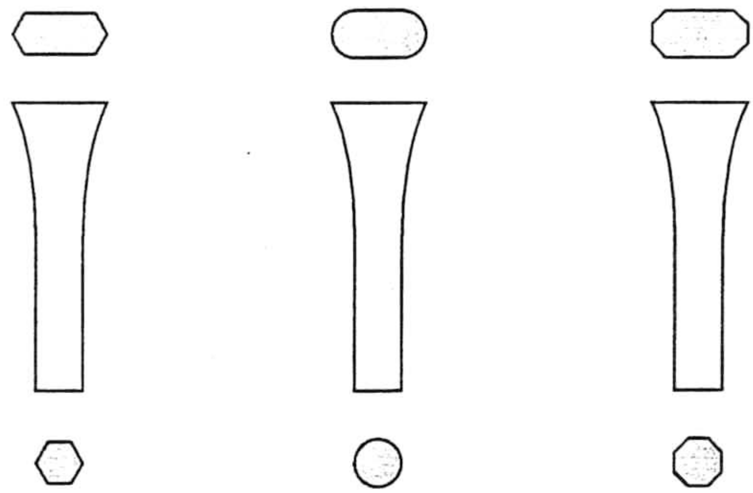


Figure 13. Standard Architectural Columns with One-Way Flare

Standard architectural columns have also been designed with two-way flare (Figure 14). These columns are nondirectional (they do not direct flow in a particular direction) and are particularly appropriate in situations involving more than one bridge, such as an interchange. Two-way flare columns are more effective from a visual judgement because the flare is evident from any viewing position.

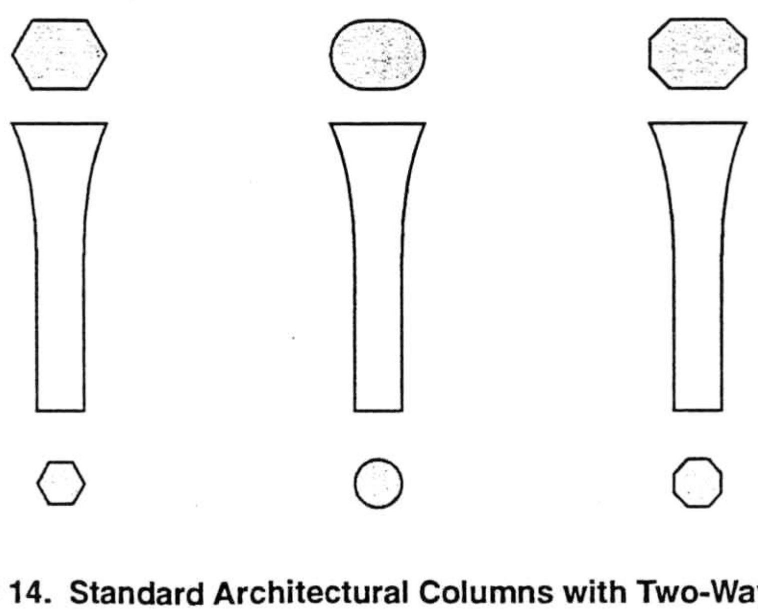


Figure 14. Standard Architectural Columns with Two-Way Flare

The lower portion of a column must connect with earth, man-made material, or water. Standard architectural columns all have vertical lower portions. Although this may not provide the best solution aesthetically, it is the only practical solution for a column that must cope with great changes in height while retaining the same width at the top.

Columns with their lower portions in water rely on the structural conditions for their shape. Columns resting on spread footings or in drilled holes can appear to disappear into the water. This is a distinct advantage with fluctuating water levels. Columns in water supported on pile caps require the pile cap to be an element in their overall design. Pile bents exposed as columns are used only when low clearance dictates the use of thin superstructure. These situations usually occur in areas of restricted clearance.

There will always be a need for nonstandard columns. Special site conditions, such as Figure 15, require an overcrossing to span a divided highway with a depression in the center for mass transit. Inadequate space for one large column presented the problem of two thin columns, resulting in a three-span structure. The structure depth would have visually overpowered the columns. The result was a massive-looking superstructure. Combining all the problems specific to the superstructure produced a unique solution where columns and superstructure appear to be in proportion with each other.

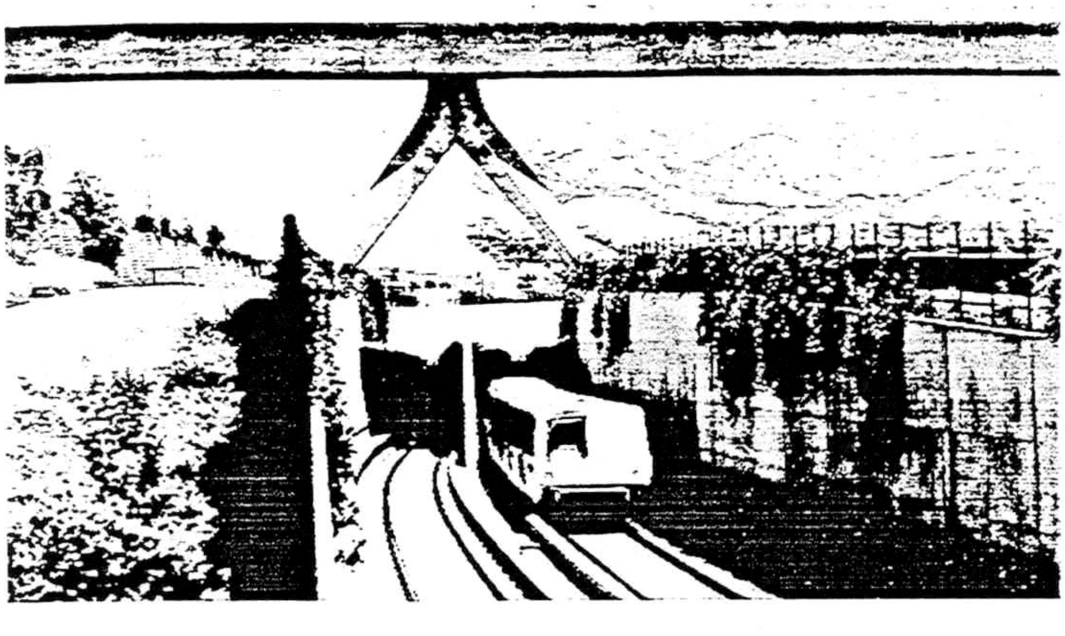


Figure 15

7.6.0 Aesthetics For Seismic Retrofit

7.6.1 General

The ideal retrofit would result in the retrofitted structure showing no change in appearance.

Real world conditions will probably dictate the use of seismic retrofit technology which will produce a change in the appearance for the retrofitted structure. This change in appearance should be minimized. Some retrofits will require additional structural parts. These functional parts should be integrated into the design of the original structure. Shape, texture, and color should be utilized to accomplish the integration.

All retrofit work affects the appearance of our structures.

The following excerpt from Memo to Designers 21-18 dated July 1989, was written to provide guidance for girder to column retrofits:

> *"Appearance of structures being retrofitted should be given consideration."*

Generally speaking:

a) If the cables are between girders, above the girder bottom flange, or are attached by means of small fittings, they are least objectionable.

b) If the cables are wound around columns or other structural members visible from a position outside the structure, they are more objectionable (Figure 16).

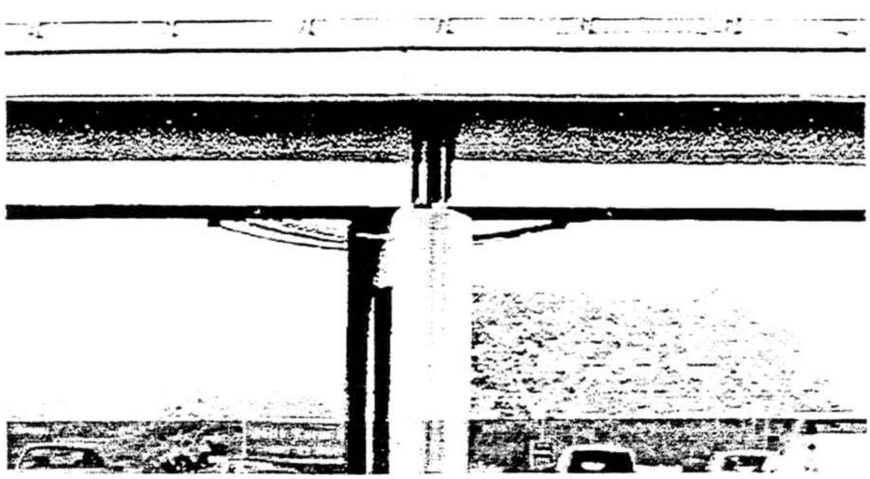


Figure 16

c) If the cables are visible in silhouette and are obviously not a part of the major structural scheme, they are most objectionable.

All of the above is further influenced by the environment: sky, background, color, character, etc.

It might be argued that precast concrete or steel beam structural types fall into a group entitled "articulated" and might be expected to contain hardware. This hardware should be minimized in size and prominence to retain its place in the general structural order.

General tidiness in detailing, a little paint, avoiding profile view contamination by the "system" and utilizing clips or secondary fasteners in lieu of cables everywhere, could help preserve the appearance of structures retrofitted by narrow-minded efforts of "restrain at all costs."

COMMENT: Place devices on interior girders if all girders do not need retrofitting and structural concerns can be satisfied.

7.6.2 Steel Column Casing

Three types of steel column casing are currently in use. For the benefit of this guide Type 1 – Prismatic Circular (Figure 17), Type 2 – Prismatic Elliptical (Figure 18), and Type 3 – Formfitting (Figure 19) will be considered.

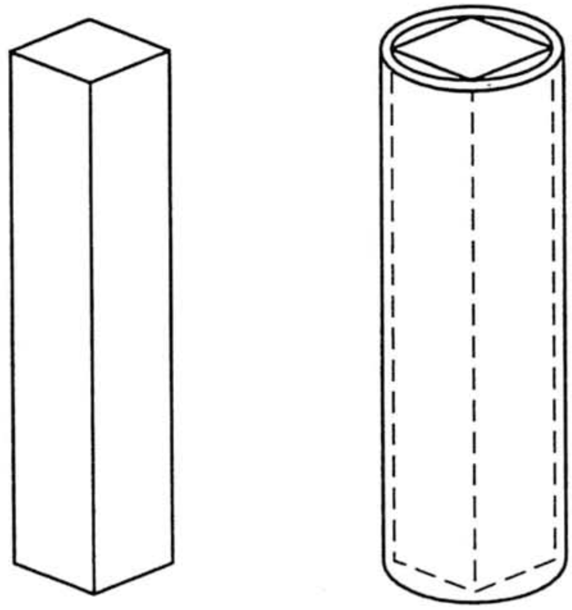
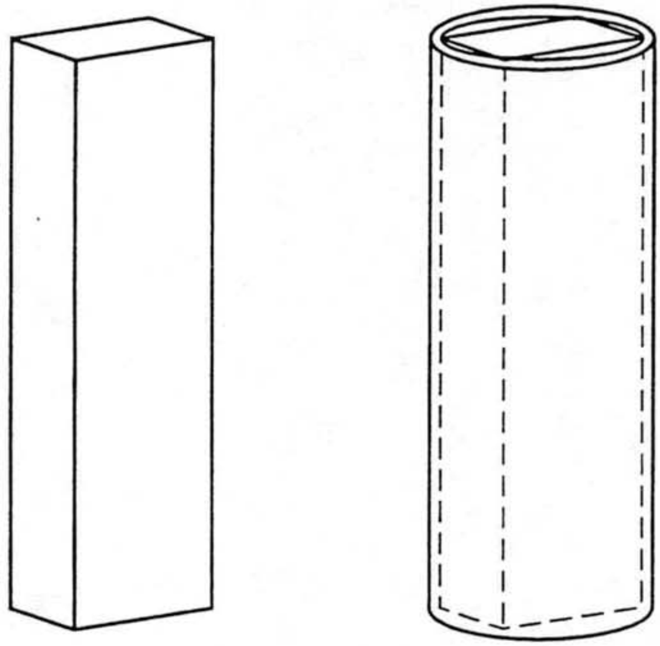
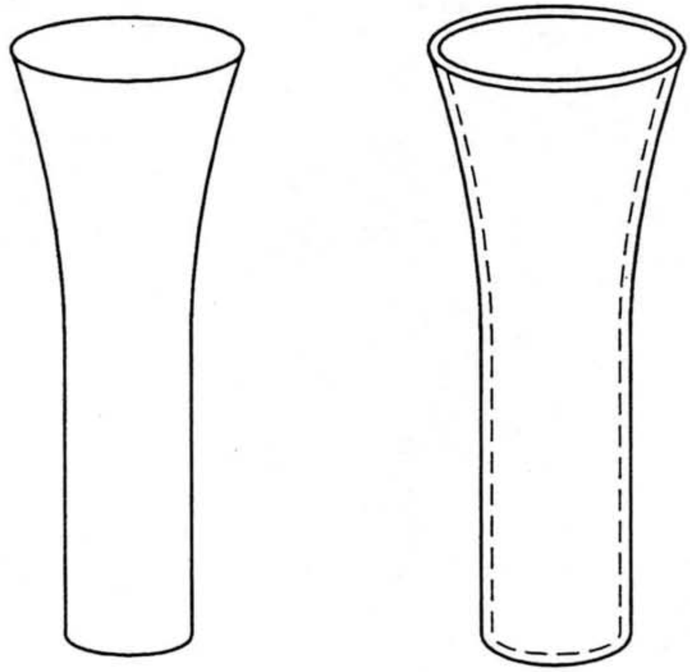


Figure 17. Prismatic Circular Steel Casing



Existing Concrete Column Elliptical Steel Casing

Figure 18. Prismatic Elliptical Steel Casing



Existing Concrete Column Form Fitting Steel Casing

Figure 19. Form Fitting Steel Casing

a) *Type 1 – Prismatic Circular* should be installed from soffit to ground continuously, minus structural gap at ends (Figure 20). The ideal use is on circular prismatic columns. Existing column cross-sections other than circular will undergo an appearance change when circular-section retrofit is installed (Figure 21). The extent of this appearance change will be greatest when all the existing columns are not retrofitted. This latter scheme is undesirable.

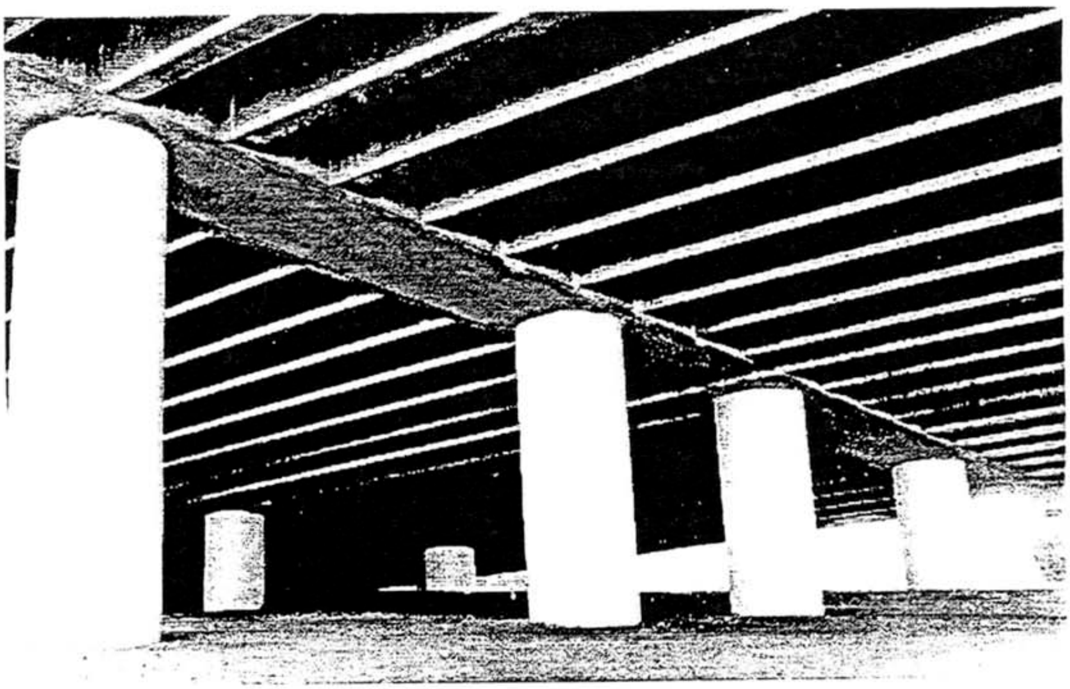


Figure 20. Circular Prismatic Steel Column Casings Extending from Ground to Soffit — Recommended

Figure 21. Partially Retrofitted Columns — Not Recommended

b) *Type 2 – Prismatic Elliptical* should be installed from soffit to ground continuously, minus structural gap at ends. The shape is the result of providing restraint without using tie rods on rectangular or oblong column cross-sections. It is difficult to determine the difference in appearance when this shape is compared to round or oblong columns in actual use (Figure 22).

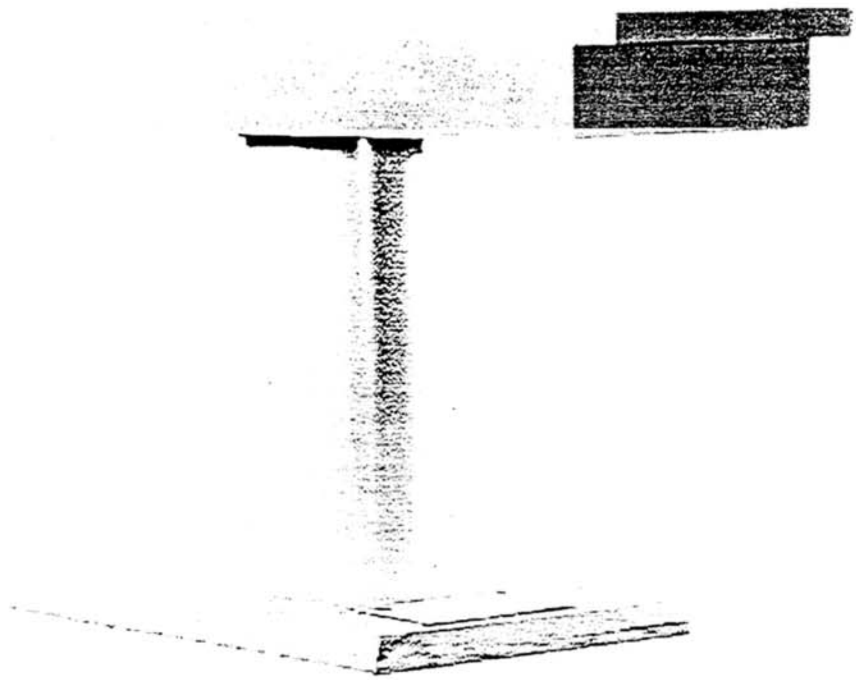


Figure 22. Elliptical Steel Column Casing — Recommended

c) *Type 3 – Formfitting* is the ideal type for flared columns and columns with cross-sections which are not circular. Examples in use have been limited to oblong flared column (Figure 23). Difficulty with restraint along the resulting flat sides has required the use of tie rods. Difficulty of elliptical casing on flared sections to meet construction tolerance for transition from prismatic section to flared section is also a problem. The ideal application would show no change in the appearance of the column after the steel casing is painted. This ideal will require the tie rods to be countersunk and filled prior to painting (Figures 24). An alternative detail would involve placing reinforcing structure on the inside of the casing (Figure 25). Although formfitting has been determined to be more expensive than some other methods, it does the best job of providing undetectable seismic retrofit, especially if the proposed details to tie bolts are utilized.

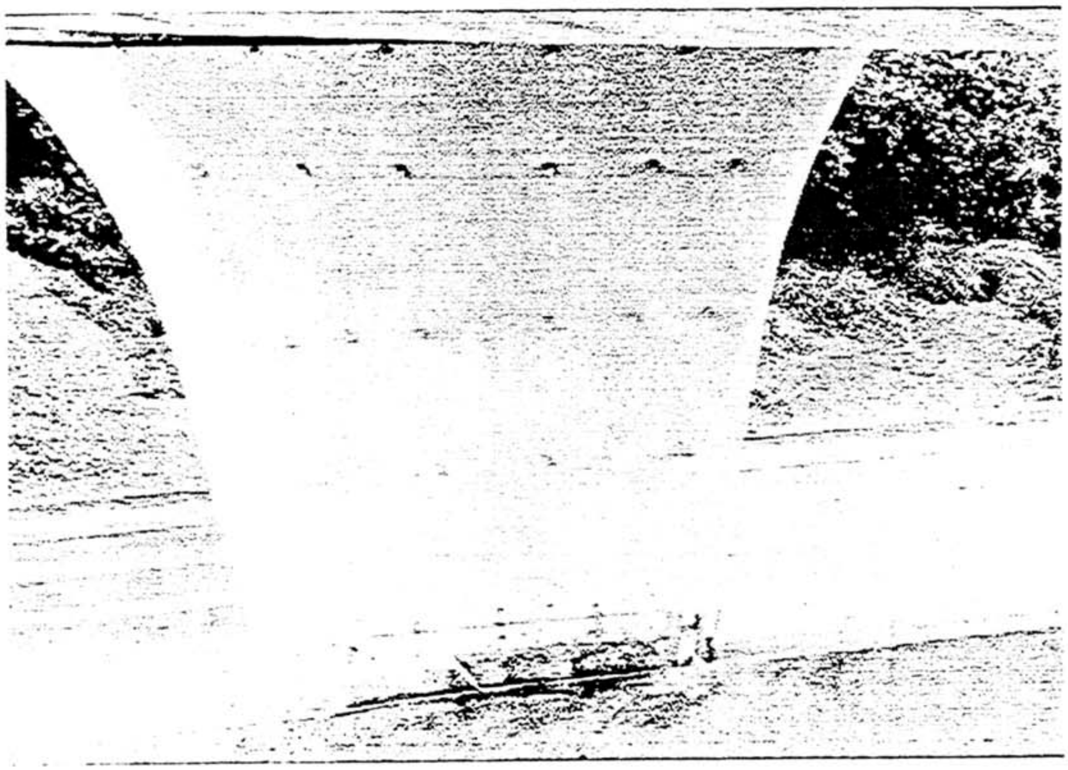
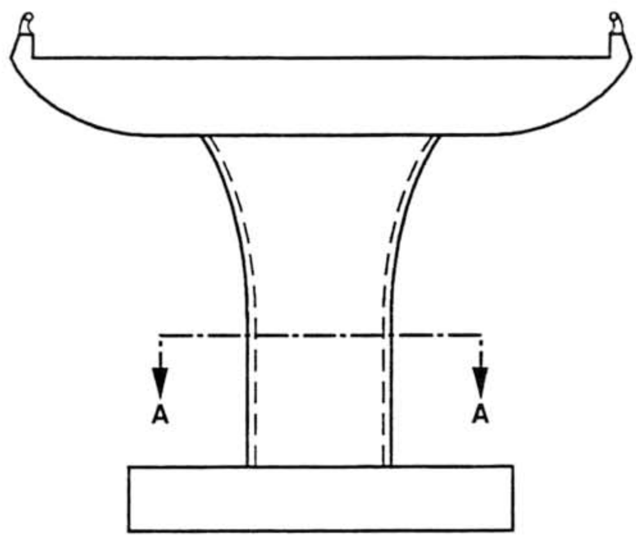
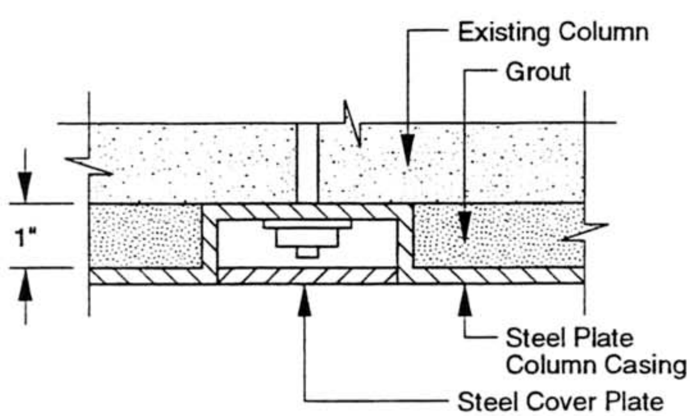


Figure 23. Form Fitting Steel Casing

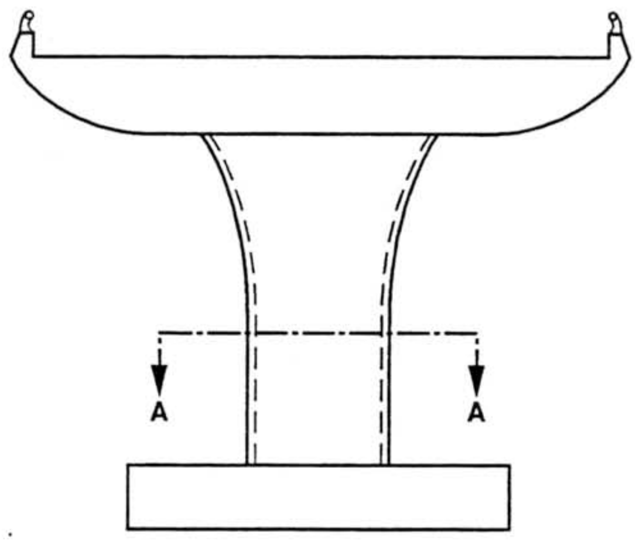


Typical Section

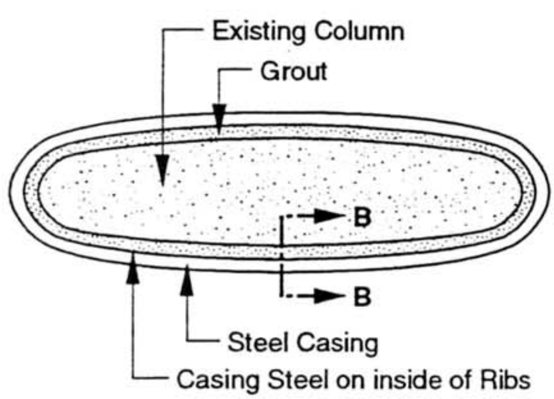


Section A-A

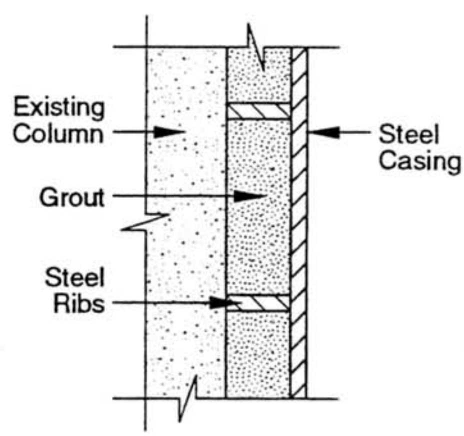
Figure 24. Proposed Detail for Eliminating Exposed Tie Rods



Typical Section



Section A-A



Section B-B

Figure 25. Proposed Detail for Eliminating Exposed Ribs

7.6.3 Fabric Wrap Casing

Experimental scale models show promise of providing seismic retrofit capability to existing columns which will make appearance change in structural capacity difficult to detect. Additional testing will be required to prove this method, which appears to offer an excellent method to retain the original appearance of our structures.

7.6.4 Cable Wrap Casing

Plastic coated steel tightly wound or wrapped around columns in a continuous spiral appears to offer a method for preserving the silhouette shape of architectural columns. There is a viewing distance from which the individual coils will not be noticed. If this distance is within the range of normal viewing in interchanges, the cable wrap seismic retrofit would be undetectable for all practical purposes; therefore, this method would accomplish our aesthetic requirement. A workable solution is available and should be considered.

7.6.5 New Replacement Columns

Generally speaking, aesthetically acceptable solutions should be considered in situations where architectural columns have been built. In these situations, retrofitting a single column bent with two new additional columns should be avoided (Figure 26). If this cannot be avoided, the new columns should be from the same architectural family or group as the existing columns (Figure 27). Constructing a new single column bent and removing the existing is the best aesthetic solution.

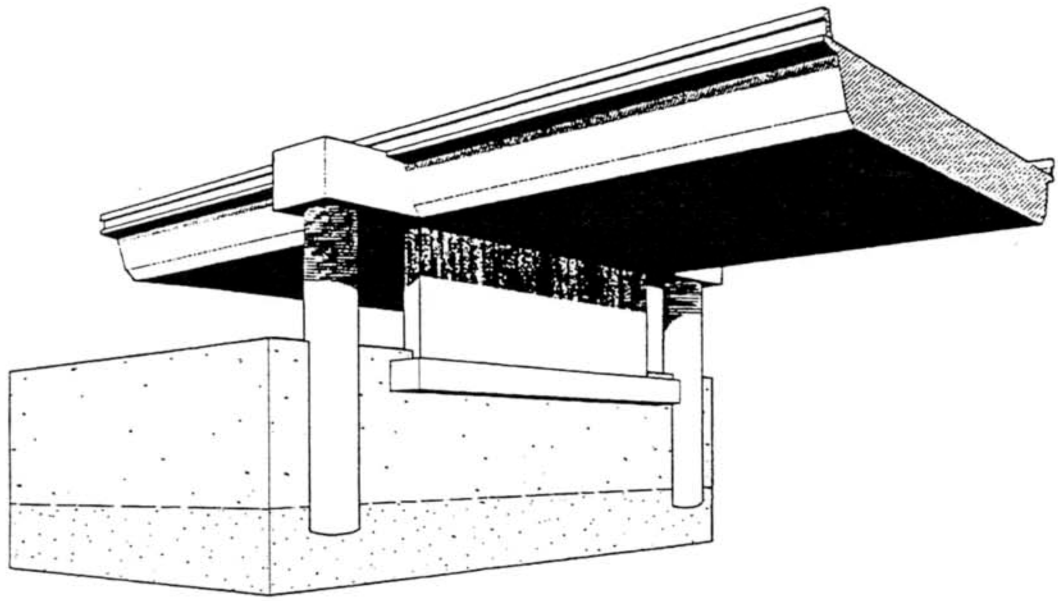


Figure 26 – Not Recommended

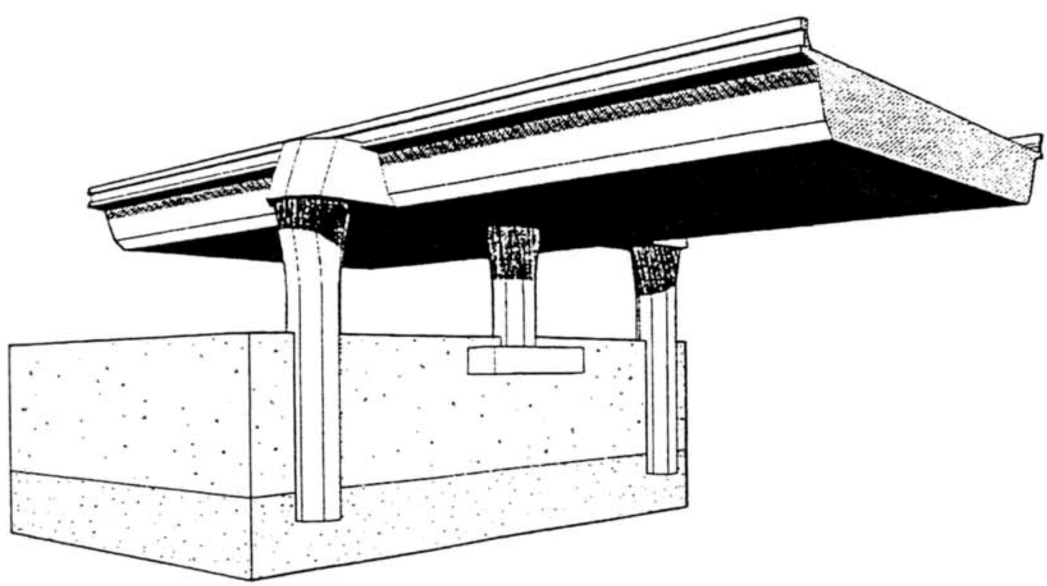


Figure 27 – Recommended

7.6.6 *Welding External Steel Plates and Tie Rods*

Protection of Weak Columns

Several methods designed to change the structure's dynamic frequency by changing the stiffness of its parts have been proposed by M. Yashinsky. Please remember Section 7.6.1 General:

"The ideal retrofit would result in the retrofitted structure showing no change in appearance."

Personnel, as well as models, are available in Aesthetics to help you achieve this goal.

7.7.0 Bibliography

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